Journal of Exposure Analysis and Environmental Epidemiology (2001) 11, 501–509

www.nature.com/jea

Quantitative analysis of children's microactivity patterns: The Minnesota Children's Pesticide Exposure Study

N.C.G. FREEMAN,[a,b] M. JIMENEZ,[a] K.J. REED,[c] S. GURUNATHAN,[c] R.D. EDWARDS,[c,g] A. ROY,[a,b] J.L. ADGATE,[e] E.D. PELLIZZARI,[d] J. QUACKENBOSS,[f] K. SEXTON[e] AND P.J. LIOY[a,b]

[a]*Robert Wood Johnson Medical School, Piscataway, New Jersey*
[b]*Environmental and Occupational Health Sciences Institute, Piscataway, New Jersey*
[c]*Rutgers University, New Brunswick, New Jersey*
[d]*Research Triangle Institute, Research Triangle Park, North Carolina*
[e]*University of Minnesota School of Public Health, Minneapolis, Minnesota*
[f]*Environmental Protection Agency, Las Vegas, Nevada*
[g]*Environmental Health Sciences, School of Public Health, University of California, Berkeley, California*

The National Human Exposure Assessment Survey (NHEXAS)/Minnesota Children's Pesticide Exposure Study (MNCPES) was a population-based study designed to characterize children's exposure to residential pesticides and to evaluate the contribution of residential and children's activities to children's exposure. Families of 168 children were surveyed for residential use of pesticides and children's activities. From these homes, families of 102 children between the ages of 3 and 13 years participated in a week-long intensive exposure study. Of the 102 children, 19 children were videotaped for four consecutive hours in their normal daily activities. The survey responses indicated that the youngest children were more likely to exhibit behaviors that would foster exposure to environmental contaminants. Comparison of questionnaire responses indicated that the videotaped subsample was representative of the exposure study population. The microactivities of the videotaped children that might contribute to their exposure *via* ingestion or dermal routes were quantified. Hand-to-mouth and object-to-mouth activities were observed most frequently among the youngest children. The youngest children were also most likely to be barefoot both indoors and outside. Gender differences were found in mouthing behavior and the proportion of observed time spent outdoors.
Journal of Exposure Analysis and Environmental Epidemiology (2001) **11,** 501–509.

Keywords: *activity patterns, children, exposure, hand-to-mouth, MNCPES, NHEXAS, pesticides.*

Introduction

Historically, exposure assessment studies have often collected information about the individual's macroactivities, i.e., where the person spends time and the duration of time in each location. As concerns about environmental contaminants from media other than air have become more prominent, there has been a concomitant need for greater level of detail about individuals' activities (Cohen-Hubel et al., 1999, 2000). For example, exposure to dust-born contaminants such as lead and pesticides may occur *via* both ingestion and dermal routes. Understanding how these exposures occur requires information about microactivities, including hand-to-mouth activities and contact with grass, soil, and surfaces. These microactivities may influence children's dermal contact with pollutants, and their ingestion of contaminants through transfer of pollutants from the environment to food through contaminated hands or directly from mouthing contaminated fingers (Quackenboss et al., 2000; Freeman et al., 2001). Detailed information about these behaviors is difficult to obtain from questionnaires but can be obtained from direct or videotaped observations (Zartarian et al., 1995, 1997a,b; Reed et al., 1999).

The Minnesota Children's Pesticide Exposure Study (MNCPES) was a phase 3 population-based study within the National Human Exposure Assessment Survey (NHEXAS) designed to characterize children's exposure to residential pesticides and to evaluate the contribution of residential and children's activities to children's exposure. MNCPES provided an opportunity to collect traditional questionnaire-based macroactivity and microactivity data about a group of 102 children and collect microactivity data from a subset of 19 children using videotaped observations. The majority of children provided urine samples for analysis of biomarkers of pesticide exposure, and house dust and hand rinse samples were collected for measurement of pesticides.

1. Address all correspondence to: Natalie C. Freeman, PhD, Environmental and Occupational Health Sciences Institute (EOHSI), 681 Frelingjuysen Road, PO Box 117, Piscataway, NJ 08855-1179. Tel.: +1-732-445-0150. Fax: +1-732-445-0116. E-mail: nfreeman@eohsi.rutgers.edu
Received 23 August 2001.

Methods

Study Population

MNCPES used a tiered approach to identify families for the study. A telephone survey was conduced to screen more than 2000 families with children between 3 and 13 years old. From this probability-based sample, 477 families were eligible to participate in a survey of in-home pesticide inventory and use, and families of 168 children completed detailed baseline residential interviews, which included questions about children's microactivities (Adgate et al., 2000; Quackenboss et al., 2000). From this group, families of 102 children between 3 and 13 years old living in the urban area of Minneapolis/St. Paul and the nonurban counties of Rice and Goodhue, Minnesota were enlisted in a week-long intensive exposure study. Child participants in this study or their parent completed a time/activity diary for 1 week, and provided questionnaire responses about pesticide usage in the home and general household activities (Adgate et al., 2000; Quackenboss et al., 2000). Because of the wide age range, questionnaire responses for children 3 and 4 years old were provided by the parent, responses were provided collaboratively by children and their parents for children 5–9 years old, and provided by the children with some support by parents for older children.

Exposure to four pesticides was investigated: chlorpyrifos, malathion, diazinon, and atrazine. Chlorpyrifos, which has recently been withdrawn from residential use, was at the time of this study the most commonly used residential insecticide in the U.S., and found in products for both indoor and outdoor use. Malathion and diazinon are commonly used outdoor insecticides, particularly on crops and flower gardens, and atrazine is a herbicide often used in corn fields (Davis et al., 1992; Whitmore et al., 1994; Simcox et al., 1995).

All children in the exposure study were encouraged to provide urine samples on three mornings during the week-long study. Of the 102 children, 87 provided three urine samples, and 90 provided at least one urine sample. These were analyzed for metabolites of chlorpyrifos, malathion, and atrazine. In addition, on the day of the second urine collection, dust samples were collected in the homes using two sampling techniques, the LWW wipe sample (Gurunathan et al., 1998) and the EL press sampler (Edwards and Lioy, 1999), and analyzed for the four pesticides (Lioy et al., 2000). Hand rinses were collected from the children on the day of the second urine collection and analyzed for the target pesticides (Lioy et al., 2000). At the time the hand rinse was collected, a tracing of the child's dominant hand was obtained on graph paper with a 1×1-cm grid and used to determine the palmer hand surface area. Additional questions were asked at this time about when hand washing was last done, and whether the child had had contact with floors, or played outdoors before the hand rinsing.

Observations

Nineteen of the 102 MNCPES children volunteered to be videotaped. Each observation was for four consecutive hours and the day of observation was not during the same week used for sample collection. Instead, it was conducted within 6 weeks of sample collection during the months of August and September 1997. Selection of the children for videotaping was based on their availability during 4 weeks that the video team was in Minnesota. Videotaping was initiated between 9 AM and 3:30 PM based on the requirements of the families. There were no differences in when the videotaping was initiated based on age of the child (Spearman correlation $r_s = -0.192$), rural or urban housing (t test, $P = 0.438$), or gender (t test, $P = 0.368$). Most of the taping sessions were conducted on consecutive days including weekdays and weekends. Because older children were in school during September, 44% of the September visits started after 3 PM, while only 13% of the August visits started this late in the day.

Analysis

Hand rinse and dust samples were analyzed for chlorpyrifos, malathion, diazinon, and atrazine at EOHSI (Edwards and Lioy, 1999; Lioy et al., 2000). Pesticide metabolites were analyzed in urine samples for three pesticides: atrazine, malathion, and chlorpyrifos, by the CDC (Hsu et al., 1988; Adgate et al., 2001). The metabolites were atrazine mercapturate, monocarboxylic acid, and 3,5,6 trichloro-2-pyridinol (TCPY). Report of the relationship between pesticides found in hand rinses and dust samples, and urinary metabolites was reported by Lioy et al. (2000).

The videotapes were transcribed using the methods reported by Reed et al. (1999). Each tape was transcribed once for the left hand and once for the right hand of each child and the frequency of each of six behaviors (hand-to-mouth, hand-to-object, object-to-mouth, hand-to-smooth surface, hand-to-textured surface, and hand-to-clothing) was recorded. In addition, the amount of time the child spent outdoors, in the home, in contact with soil or grassy surfaces, and whether the child was barefoot, was recorded from the tapes. Quality control procedures for the tape transcription included repeat analyses of tape segments, where coefficients of concordance of at least 0.85 were required for all transcribed behaviors (Reed et al., 1999). Two individuals transcribed the videotapes, a primary transcriber who transcribed all the tapes, and a secondary one who selected 20% of the tapes at random for comparison between transcribers. The primary transcriber also retranscribed 20% of the tapes for internal comparison. Additional analysis of videotapes were conducted for four children selected at random using the VideoTraq transcription system (Zartarian et al., 1995) to compare the frequencies of behaviors obtained using the VideoTraq and Reed methods of transcription. The VideoTraq system uses

Table 1. Percent of children with reported behaviors from the telephone survey conducted in the MNCPES (n=168).

Reported behavior	Percent reported by age group		
	3–4 years (n=27)	5–9 years (n=93)	10–12 years (n=48)
Often places thumb/fingers in mouth	56	39	35*
Often puts nonfood items in mouth	52	31	37
Often eats food dropped on floor	48	10	4**
Often eats most food without utensils	37	29	19*
Often puts paint chips in mouth	0	0	0
Often carried around blanket/toy	74	–	–
Often slept with blanket/toy	70	–	–
Often placed toes in mouth	15	–	–
Often or sometimes eats soil	15	–	–
Often used pacifier that had fallen on floor	11	–	–
Often/sometimes chewed furniture/sills	4	–	–
Often/sometimes used bottle that had fallen on the floor	4	–	–

χ^2 test, **significant difference across three groups, *P<0.10 between youngest and oldest groups.

a computer program to score location of the child, level of activity, and frequency and duration of up to 16 separate activities (Zartarian et al., 1997b).

Statistical analysis was conducted using SPSS® and Systat®. Both parametric and nonparametric analyses were used as appropriate for the size and shapes of the distributions. Student t tests and Mann–Whitney tests were used for comparing gender differences in behaviors, exposure metrics, and hand surface areas. Chi-square tests and Fisher exact probabilities were calculated for responses by age groups, Spearman correlations were calculated for comparisons against the ages of the children, and Kendall's coefficient of concordance were used for within transcriber and between transcriber orderings of the six observed behaviors.

Results

Survey Responses

The baseline survey was conducted in the homes of 168 children and captured detailed information about children's microbehaviors that might contribute to exposure to environmental contaminants. Five questions were asked about the behavior of all children: (1) did they often put paint chips in their mouth, (2) did they often eat most food without utensils, (3) did they often eat food that had dropped on the floor, (4) did they put nonfood items in their mouth, and (5) did they often place thumb or fingers in the mouth. When the children were divided into three age groups: 3–4 year olds (preschool), 5–9 year olds (young primary), and 10–12 year olds (old primary), only one item, eating food dropped on the floor, was significantly different across the three age groups with younger children reported to be more likely to exhibit the behavior (Table 1) based on a χ^2 test for equality of proportions (P<0.001). Marginal differences between the youngest and oldest groups were found for use of utensils (χ^2=3.014, P=0.083) and putting thumb/fingers in mouth (χ^2=2.827, P=0.093).

When responses to the questions were further broken down by age (Table 2), 3-year-old children had significantly more positive responses compared to nearly every other age group. The decline in positive responses differed across questions with some behaviors such as putting thumbs/fingers in the mouth and putting nonfood items in the mouth persisting across ages.

Seven additional questions were directed specifically toward 3- and 4-year-old children. Two were related to carrying about and sleeping with blankets or toys. Other questions concerned use of pacifier, bottle, chewing on

Table 2. Percent of children with reported behavior by age.

Reported behavior	Age (years)									
	3 (n=14)	4 (n=13)	5 (n=15)	6 (n=24)	7 (n=18)	8 (n=15)	9 (n=21)	10 (n=16)	11 (n=21)	12 (n=12)
Thumb/fingers in mouth	71	63	33	50	28	33	43	38	33	33
Nonfood items in mouth	71	31	20	29	28	40	38	38	48	17
Eat food dropped on floor	71	23	27	8	11	0	5	6	5	0
Eat without utensils	54	25	33	38	11	20	24	13	29	8
Carry blanket/toy	86	62	–	–	–	–	–	–	–	–
Sleep w/ blanket/toy	86	54	–	–	–	–	–	–	–	–
Eat soil	31	0	–	–	–	–	–	–	–	–
Toes in mouth	29	0	–	–	–	–	–	–	–	–
Pacifier on floor	27	0	–	–	–	–	–	–	–	–

furniture or window sills, soil consumption, and mouthing toes. Based on the high response rates for these younger children, the questions related to carrying around and sleeping with blankets/toys should have been asked of the older children. Since more than 70% of the youngest children were reported to exhibit these behaviors, it is very likely that older children also show the behaviors. In contrast, placing toes in the mouth would be unexpected in older children simply because the changes in body proportions and flexibility with age would prohibit this activity.

Comparison of Videotaped Children (n= 19) and Nonvideotaped Children (n= 83)

Data on the videotaped subset of children were compared to the rest of the children participating in the exposure study to determine whether the children who participated in the videotaping were representative of the entire MNCPES group. Age and gender distributions were similar to the study group from which the subset was drawn. Mean age of the videotaped children was 7.5±2.8 years compared to 8.1±2.8 years (t test, P=0.39) for those not videotaped. The one discrepancy in the age distribution was the fact that no 9-year-old children participated in the video sessions. Hand surface area, which is associated with the age of the child, was also similar for both groups: 83±25 and 90±23 cm^2, respectively (t test, P=0.28). Gender distribution was similar; 44% of the videotaped children were boys compared to 48% of the nonvideotaped children. Regional distributions were also similar with 69% of the non-videotaped children coming from the Minneapolis/St. Paul area and 31% from the suburban/rural counties of Rice/Goodhue, while 59% of the videotaped children came from the Minneapolis/St. Paul area and 41% from the suburban/rural areas.

Comparison of activity data reported by the children at the time of hand rinses suggested that the videotaped children had activity patterns that were similar to those who were not videotaped. The behaviors reported for the two groups are summarized in Table 3. The activities compared are those that the child or parent reported for the time period before hand rinse collection. There were no significant differences in these activities reported the two groups.

Several age-based activities were identified. For the entire MNCPES group, younger children were more likely to report sitting on the floor before the hand rinse (sit on floor mean age 7.6±2.9 years, did not sit on floor mean age 9.4±2.3 years, t test P=0.006). Using hand palm surface area as a surrogate for age, the results were similar (sit mean hand area 85±24 cm^2, did not sit mean hand area 98±20 cm^2, t test, P=0.011). In contrast, there was no difference by age for reported playing outdoors before hand rinse. These same patterns were observed for the subgroup that was videotaped. Among videotaped children, younger children were more likely to be barefoot than older children. The average age of barefoot children was 5.8±1.7 years, while the average age of children who wore shoes during the video observation was 8.2±3.0 years (t test, P=0.048).

Daily time/activity diaries were completed every day during the week of environmental sampling by the children or their parents for the youngest children. No significant differences were found in time–activity diary responses between the videotaped and nonvideotaped children related to amount of time the children spent in various venues. The children or their parents reported amount of time spent indoors at home, at school, or elsewhere, outdoors at home, and in transit. Both groups tended to spend about 16 h each day in the home, and approximately 1–1.5 h outdoors.

Additional diary activity questions covered water consumption habits, hygiene, travel in cars, exposure to tobacco smoke at home and in vehicles, contact with soil, grass and leaves, exposure to gasoline and pesticides, and levels of activity on each of the 7 days of the exposure study. There were no significant differences for most of these activities between videotaped and nonvideotaped children. Several items showed slight (Mann–Whitney test, P<0.10) or significant (P<0.05) differences between the groups, but these differences were not consistent across all days of the study. Children participating in the videotaping reported fewer minutes of exposure to tobacco smoke indoors on 3 of the 7 days on which the diary was completed compared to those not participating in the

Table 3. Activities reported for the time between the last hand washing and the collection of hand rinse sample.

Reported activity	Percent of children with reported activity patterns	
	Videotaped children (n=19)[a]	Nonvideotaped children (n=83)[2]
Sit on floor (%)	77	73
Play outdoors (%)	52	68
Neither sit on floor/nor play outdoors (%)	12	13
Both sit on floor and play outdoors (%)	47	55

[a]Hours since wash hands: median 3.0 h, range 1–15 h.
[b]Hours since wash hands: median 4.3 h, range 1–48 h.

Table 4. Median observed activity rate per hour (mean±SD) based on 4 h of observation per person. The rate of activity is based on the number of hand contacts made per hour.

Observed activity	Age category (years)			
Children	*n*=3	*n*=7	*n*=4	*n*=5
Person-hours	*n*=12	*n*=28	*n*=16	*n*=20
	3–4	5–6	7–8	10–12
Object-to-mouth***	3 (6±7)	0 (1±2)	0 (1±2)	0 (1±1)
Hand-to-mouth	3.5 (4±4)	2.5 (8±13)	3 (5±7)	2 (4±6)
Touch clothing**	26 (34±21)	22 (26±23)	50 (54±43)	35 (53±66)
Touch textured surface	40 (52±61)	20 (32±40)	22 (58±88)	16 (24±31)
Touch smooth surface*	134 (151±62)	111 (120±77)	120 (155±119)	94 (96±50)
Touch object	130 (153±108)	117 (132±88)	111 (164±148)	127 (179±126)

Kruskal Wallis test comparison across four age groups: ***P=0.002, **P=0.0796, *P=0.1108.

videotaping (Mann–Whitney test, mean minutes: day 1: 6 vs. 37 min, P=0.05; day 3: 6 vs. 38 min P=0.05; day 5: 13 vs. 43 min, P<0.10). Soil contact was reported more frequently by videotaped children on 2 days (Fisher exact probability test: day 1, day 2, P=0.05; day 3, P=0.075), and contact with grass or leaves was reported more frequently by videotaped children on 2 days (Fisher exact probability test: day 2, P=0.065; day 4, P=0.067). In addition, videotaped children were more likely to report having bathed than non videotaped children (Fisher exact probability test: day 1, P=0.021; day 2, P=0.07). For the rest of the week-long period, there were no significant differences between the groups.

Microactivities of Videotaped Children

The videotaped children ranged from 3 to 12 years old. Age differences for observed activities were assessed by dividing the children into four age categories: 3–4 years, 5–6 years, 7–8 years, 10–12 years. Hand activities were quantified based on both total person-hours (n=76) for the 19 children (Table 4). The frequency of six activities was obtained from the videotapes: placing nonfood objections in the mouth, placing fingers or hand in the mouth, touching clothing, touching textured surfaces such as carpets and upholstered furniture, touching smooth surfaces such as wood or plastic furniture or hardwood floors, touching objects such as toys, pencils or other things that can be manipulated.

The only variable that was statistically different across age groups was object-to-mouth activities. Multiple range tests indicated that object-to-mouth activities were significantly greater for the 3 year olds than any other group. Two other activities showed slight, but not statistically significant, differences across ages: (1) contact with clothing was most frequent among the two oldest groups of children (7–8, and 10–12 years), and (2) hand contact with smooth surfaces such as tables or floors was least frequent among the oldest children (10–12 years).

Gender differences were observed in some activities during the videotaped activities (Table 6). During the 4 h of observation, boys spent significantly more time outdoors than girls, 105±5.9 compared to 54±37 min, respectively (t test, P=0.05). Girls were observed to place their fingers in their mouth more frequently than boys. When adjusted for the time spent indoors, the rate of hand-to-mouth activities indoors for girls was 8.1±5.5 times per hour compared to 4.7±6.5 times per hour for boys (t test, P=0.031). For both boys and girls, hand-to-mouth and object-to-mouth activities were less frequent outdoors than indoors (Table 5).

Comparisons of the Reed manual counting system and VideoTraq computer-based system of video transcription of the frequency of contacts with skin, textured surfaces, smooth surfaces, objects, and hand-to-mouth behaviors indoors and outdoors was conducted for four of the children and revealed no significant differences in the frequency of events (Mann–Whitney test, P>0.05 for each category of activities). Use of the VideoTraq program allowed for calculating both frequency and duration of contacts, and for creating subgroups of objects and surfaces. For example, the broader category "textured surfaces" was broken down into "carpets" and "upholstered furniture," while "objects" was broken down into "paper," "hard toys," "plush toys," "pets," "food," etc.

Table 5. Comparison of observed activities for boys and girls (mean±SD).

Observed activity	Boys (n=8)	Girls (n=11)
Hours since last hand wash	5.9±5.2	3.5±2.5
Time spent outdoors (minutes)*	104.4±59.2	54.0±37.4
Time spent indoors (minutes)*	134.3±57.0	186.0±37.4
Hand-to-mouth indoors/hour*	4.7±6.5	8.1±5.5
Hand-to-mouth outdoors/hour	1.7±3.9	2.3±3.9
Object-to-mouth indoors/hour	1.0±0.9	2.6±3.4
Object-to-mouth outdoors/hour	0.1±0.2	1.0±1.9

*P<0.05 by Mann–Whitney test.

Table 6.

a: Example of hand contact event frequency and median duration of individual events reported in seconds and (range) of an 8-year-old girl for approximately hour-long periods in each of three locations.

Contact activity	Location					
	Bedroom		Family Room		Yard	
	Frequency	Median duration	Frequency	Median duration	Frequency	Median duration
Hard floor	–	–	2	4 (3–5)	–	–
Hard surfaces	–	–	23	29 (1–207)	32	9 (2–65)
Upholstered surfaces	11	4 (2–13)	32	5 (1–117)	–	–
Carpet/rug	10	10 (1–103)	–	–	–	–
Hard toys	41	27 (1–271)	20	9 (3–14)	41	8 (1–59)
Plush toys	–	–	2	2 (1–2)	–	–
Paper/cards	9	15 (1–550)	3	22 (13–59)	–	–
Clothes	3	2 (1–2)	15	4 (1–25)	28	7 (1–209)
Hair	1	1	6	4 (2–29)	12	5 (2–29)
Skin	5	3 (1–13)	38	7 (1–93)	26	14 (1–110)
Food	–	–	–	–	1	156
Grass	–	–	12	1 (1–2)	38	2 (1–14)
Nothing	9	20 (1–47)	3	10 (1–123)	80	4 (1–13)
Not observable	8	6 (2–18)	29	10 (1–312)	14	12 (1–41)
Total time (min)	54		67		55	

b: Example of hand contact event frequency and median duration of individual events reported in seconds and (range) for a 6-year-old girl in approximately 2-h periods in each of two locations.

Contact activity	Location			
	Family Room		Porch	
	Frequency	Median duration	Frequency	Median duration
Hard floor	10	3.5 (2–8)	–	–
Hard surfaces	43	7 (1–302)	40	10 (2–276)
Upholstered surfaces	10	4 (1–55)	–	–
Hard toys	38	15 (2–148)	65	21 (1–231)
Plush toys	2	1	–	–
Paper/cards	10	9.5 (2–78)	19	5 (1–113)
Clothes	27	5 (1–137)	12	6 (3–21)
Hair	12	4.5 (2–39)	1	1
Skin	59	15 (1–546)	18	7 (1–39)
Food	–	–	12	29.5 (1–138)
Water	–	–	5	3 (2–17)
Dirt	–	–	1	1
Grass	–	–	26	13 (1–49)
Nothing	53	5 (1–38)	50	8 (1–38)
Not observable	20	8 (1–44)	20	9 (2–79)
Total time (min)	110		108	

Table 6a shows the hand contact frequencies and median duration for a range of activities that an 8-year-old girl displayed (1) in her bedroom while resting and playing quiet games, (2) while playing in the family room, and (3) while in the yard. Table 6b shows similar data for activities displayed by a 6-year-old girl (1) in the family room and (2) in a porch used as a play room.

Duration of contact events for the four children whose tapes were transcribed using VideoTraq were typically short, on the order of 3–5 s per contact. Duration of contact

greater than 10 s per event was observed under very specific conditions. Contact with pets, while observed infrequently (three children, 30 contacts), had a median duration of 13 s (range 4–123 s). Food items were typically held in the hand for more than 10 s before being eaten or placed on a surface. Median duration of food contacts was 18 s (range 2–179 s). In addition, when children were inactive, such as watching television or resting on a chair, couch, carpet, or bed, contact duration with toys increased to a median of 29 s per event (range 2–271 s) compared to a median contact time with toys of 10 s (range 1–231 s) during active play. During inactive periods, contact with hair was also observed, particularly among the girls. Hair contact was infrequently observed during active play. Most hand-to-mouth and object-to-mouth activities were observed during the children's inactive periods, particularly when watching television. Prolonged contact with paper goods (>10 s) was also observed when children were playing card and board games.

Relation of Children's Activities to Pesticide Hand Loading
Chlorpyrifos was found on the hands of half of the MNCPES children. Few children had measurable amounts of the other pesticides on their hands (Lioy et al., 2000). At the time of hand rinse, children were asked when they last washed their hands, and if they had played outside, or on the floor inside. There was no association between the number of hours since hand washing and the loading of chlorpyrifos on the children's hands (Spearman correlation $r_s = -0.044$). Similarly there was no significant relationship between age of child and chlorpyrifos loading ($r_s = 0.013$). There were no significant differences in chlorpyrifos hand loading based on whether the child sat on the floor or played outside.

Discussion

The observational data from MNCPES expands the existing microactivity data base of observational studies, which consists primarily of toddlers (Zartarian et al., 1997a,b, 1998; Reed et al., 1999) to include observations of 19 children aged 3–12 years. While the sample size is small, the findings are consistent with the work by Zartarian and Reed, and suggest that mouthing activities are greater for 3-year-old children than for older children. However, even children 10–12 years old exhibited hand-to-mouth behaviors, typically while watching television. In this small sample, the rate of contacts with surfaces and objects in the child's environment did not show significant age trends.

Previous work by Zartarian et al. (1995,1997a,b,1998) and Reed et al. (1999) with preschool children found higher rates of hand-to-mouth activities than we found in this study for similarly aged children (nine vs. six times per hour). However, since there were only three preschool children in this study the difference may not be meaningful. This study found a decline in both reported and observed hand-to-mouth behavior with age. Because no children less than 3 participated in this study and our 3-year-old children had the highest rate of hand-to-mouth behaviors, we do not know when peak hand-to-mouth activity occurs. Based on the work of Reed et al. (1999) it is likely that even younger children have higher rates of mouthing.

The duration of contacts for the four children whose tapes were transcribed by VideoTraq are consistent with the findings of Zartarian et al. (1997a,b,1998). Most of children's contacts with their environment are very short in duration, typically less than 5 s. However, while short in duration, contacts are very frequent allowing for many opportunities for contact with contaminants. The results suggest that dermal contact with environmental contaminants on surfaces and objects is a potential problem throughout childhood, while activities such as hand-to-mouth and object-to-mouth behaviors contributing to nondietary ingestion may decline with age. At the same time, hand washing was infrequently observed to precede food handling and consumption, suggesting that contaminants on children's hands could transfer to food and be ingested.

A methodological issue of concern is that the baseline questionnaire and time–activity diary for the youngest children were routinely completed by the parent, while the older children were more likely to be the primary respondent helped by the parent. We do not know if this influenced the types of responses obtained. However, we did find that parental reports of mouthing behavior were consistent with the greater frequency of observed mouthing behaviors in the youngest children when compared to the older children. The benefit of observations is that it does not rely on potentially biased responses and can act as a form of validation of questionnaire responses. One problem with the execution of the baseline questionnaire was the *a priori* decision not to ask all microactivity questions to all the children. We may have missed information about the microbehaviors of older children based on this decision.

The time–activity diary contained 27 questions that the participants or their parents completed on each of the 7 days of the exposure study. Based on chance it would not be unexpected to find as many as 20 significant differences between age groups of children over the 7-day period, or between videotaped and nonvideotaped children. In fact, there were very few differences.

The potential for extensive dermal contact was also observed as the children in the summer of 1997 played in shorts or bathing suits both indoors and outdoors, although

these body and leg contacts with soil, sand, grass, and floor were not quantified. The younger children were observed to go barefoot, and this was less frequently observed among the older children. The potential for hand contact with pesticides on surfaces and objects and transfer of contaminated hands to the mouth or to food items was observed. The 19 children who were videotaped were never observed to wash their hands after playing outdoors. Few children were observed to wash their hands before lunch, and often children would go from outdoor play to getting a snack in the kitchen without hand washing. Some children were observed to carry and eat snacks as they played outdoors thereby affording an additional opportunity for food contamination.

While gender differences in behavior were observed in this study, there was no difference in urine metabolite levels between boys and girls (Adgate et al., 2001). Since we do not know all the sources of exposure for these children, we cannot at this point determine what is the relationship between the children's behaviors and their exposure. Since the sample size of observed children was small, it is unclear whether the gender differences would persist in a larger study.

The videotapes were collected at a separate time from the intensive monitoring period; therefore, the relationship between the observed behaviors to biomarkers of exposure or hand rinse pesticide levels is uncertain. Additional studies in which the observational data are collected at the same time as exposure metrics, and with larger numbers of young children who exhibit high rates of mouthing will clarify the relationship of hand-to-mouth activity and reported activities that contribute to nondietary ingestion and exposure. It should be noted that it was more difficult to obtain three urine samples from the younger children than it was from school-aged children. Because of the difficulties in collecting urine samples from the younger children, adequate data are lacking on biomarkers of exposure for toddlers and preschool aged children. The observational and survey data gathered in this study suggest that it is important to gather more urinary biomonitoring and activity pattern data information on younger children.

Acknowledgments

The authors thank the families that participated in this study and allowed us into their homes. We acknowledge the VideoTraq transcriptions carried out by Lavinia Thompson. This study was funded through the National Human Exposure Assessment Survey (NHEXAS) Region 5 Environmental Protection Agency (EPA) cooperative agreement CR821902-01-0 to Research Triangle Institute and Environmental and Occupational Health Sciences Institute (EOHSI), and by EPA Science to Achieve Results (STAR) grant R825282 to the University of Minnesota. Drs. Lioy and Freeman are also supported by the NIEHS Center grant (ES05022-12). Although the research described in this article has been funded in part by the EPA, it has not been subjected to review and, therefore, does not necessarily reflect the views of the agency, and no official endorsement should be inferred.

References

Adgate J.L., Barr D.B., Clayton C.A., Eberly L.E., Freeman N.C.G., Lioy P.J., Needham L.L., Pellizzari E.D., Quackenboss J.J., Roy A., and Sexton K. Measurement of children's exposure to pesticides: analysis of urinary metabolite levels in a probability-based sample. *Environ Health Prospectives* 2001: 109: 583–590.

Adgate J.L., Clayton C.A., Quackenboss J.J., Thomas K.W., Whitmore R.W., Pellizzari E.D., Lioy P.J., Shubat P., Stroebel C., Freeman N.C.G., and Sexton K. Measurement of multi-pollutant and multi-pathway exposures in a probability-based sample of children: practical strategies for effective field studies. *J Exposure Anal Environ Epidemiol* 2000: 10: 650–661.

Cohen-Hubel E., Sheldon L., McCurdy T., Rigas M., Burke J., Zartarian B., and Freeman N.C.G. Exposure assessment for children: a review of the factors influencing exposure of children, and the data available to characterize and assess that exposure. *Environ Health Perspect* 1999: 108: 475–486.

Cohen-Hubel E., Sheldon L., Zufall M., Burke J., and Thomas K.W. The challenge of assessing children's residential exposure to pesticides. *J Exposure Anal Environ Epidemiol* 2000: 10: 638–648.

Davis J.E., Brownson R.C., and Garcia R. Family pesticide use in the home, garden, orchard, and yard. *Arch Environ Contam Toxicol* 1992: 22: 260–266.

Edwards R.D., and Lioy P.J. The EL sampler: a press sampler for the quantitative estimation of dermal exposure to pesticides in house dust. *J Exposure Anal Environ Epidemiol* 1999: 9: 521–529.

Freeman N.C.G., Sheldon L., Jimenez M., Melnyk L., Pellizzari E.D., and Berry M. Contribution of children's activities to lead contamination of food. *J Exposure Anal Environ Epidemiol*. 2001. in press.

Gurunathan S., Robson M., Freeman N., Buckley B., Roy A., Meyer L., Bukowski J., and Lioy P.J. Accumulation of chlorpyrifos on residential surfaces and on/in toys accessible to children. *Environ Health Perspect* 1998: 106: 9–16.

Hsu J.P., Wheeler H.G., Schattenberg H., et al. Analytical methods for determining non-occupational exposures to pesticides. *J Chromatogr Sci* 1988: 26: 181–189.

Lioy P.J. Edwards R., Gurunathan S., Freeman N.C.G., Pellizzari E., Sexton K., and Quackenboss J. Residential pesticide levels measured by the EL and LWW sampler and comparisons to hand rinses and urine metabolite levels. *J Exposure Anal Environ Epidemiol* 2000: 10: 327–340.

Quackenboss J.J., Pellizzari E.D., Shubat P., Adgate J.L., Thomas K.W., Freeman N.C.G., Whitmore R.W., Stroebel C., Lioy P.J., Clayton A., and Sexton K. Design strategy for a multi pathway pesticide exposure study in children. *J Exposure Anal Environ Epidemiol* 2000: 10: 145–158.

Reed K.J., Jimenez M. Freeman N.C., and Lioy P.J. Quantification of children's hand and mouthing activities through a videotaping methodology. *J Exposure Anal Environ Epidemiol* 1999: 9: 513–520.

Simcox N.J., Fenske R.A., Wolz S.A., Lee I.C., and Kalman D.A.

Pesticides in household dust and soil: exposure pathways for children of agricultural families. *Environ Health Perspect* 1995: 103: 1126–1134.

Whitmore R.W., Immerman F.W., and Camehn D.E. Non-occupational exposures to pesticides for residents of two U.S. cities. *Arch Environ Contam Tox* 1994: 26: 47–59.

Zartarian V.G., Furguson A.C., and Leckie J.O. Quantified dermal activity data from a 4-child pilot field study. *J Exposure Anal Environ Epidemiol* 1997: 7: 543–553.

Zartarian V.G., Ferguson A.C., Ong C.G., and Leckie J.O. Quantifying videotaped activity patterns: video translation software and training methodologies. *J Exposure Anal Environ Epidemiol* 1997: 7: 535–542.

Zartarian V.G., Furguson A.C., and Leckie J.O. Quantified mouthing activity data from a 4-child pilot field study. *J Exposure Anal Environ Epidemiol* 1998: 7: 543–554.

Zartarian V.G., Streiker J., Rivera A., Cornejo C., Molina S., Valadez O., and Leckie J.O. A pilot study to collect micro-activity data of 2–4 year old farm labor children in Salinas Valley, California. *J Exposure Anal Environ Epidemiol* 1995: 5: 21–24.